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PRECIPITATION and STREAMFLOW of a COLORADO FRONT RANGE WATERSHED

Station Paper No. 47

March 1960

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Raymond Price, Director Fort Collins, Colorado
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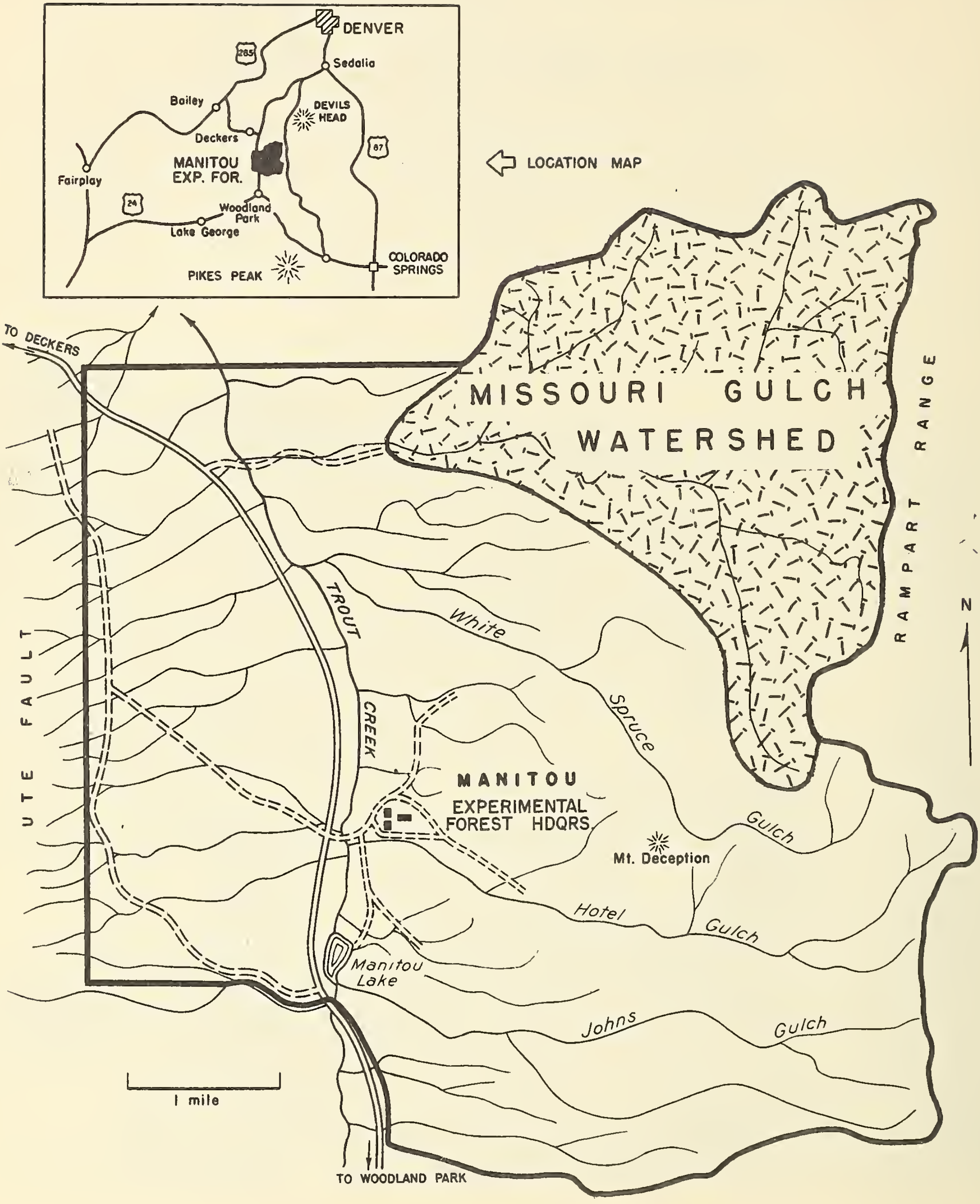

DENVER
285
Sedalia
Bailey
DEVILS HEAD
Deckers
87
MANITOU EXP. FOR.
Fairplay
24
Woodland Park
Lake George
COLORADO SPRINGS
PIKES PEAK
LOCATION MAP
TO DECKERS
MISSOURI GULCH WATERSHED
RAMPART RANGE
N
UTE FAULT
TROUT CREEK
White Spruce Gulch
MANITOU EXPERIMENTAL FOREST HDQRS
Mt. Deception
Hotel Gulch
Manitou Lake
Johns Gulch
1 mile
TO WOODLAND PARK

PRECIPITATION AND STREAMFLOW OF A COLORADO FRONT RANGE WATERSHED

by

Herbert W. Berndt, ~~Forester~~
Rocky Mountain Forest and Range Experiment Station[1]

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[1] Central headquarters at Fort Collins, Colorado, in cooperation with Colorado State University

PRECIPITATION AND STREAMFLOW
OF A COLORADO FRONT RANGE WATERSHED

by

Herbert W. Berndt

- - -

Knowledge of the water-yielding characteristics of a variety of drainages is important in watershed management. This report presents information obtained during 1940-58 from the Missouri Gulch watershed on the Manitou Experimental Forest in Colorado. The purpose of the study was to gain information on water yield and its relation to precipitation for a drainage heading in the Colorado Front Range ponderosa pine type.

TOPOGRAPHY

Missouri Gulch watershed covers 7.2 square miles and lies in the northern part of Manitou Experimental Forest. It heads in the Rampart Range at approximately 9,300 feet elevation and flows generally westward to its confluence with Trout Creek at 7,500 feet elevation. Slopes ranging from 10 to 60 percent are predominantly north- and south-facing. North-facing slopes are generally the steeper.

Steep slopes and erodible soils derived from granite have resulted in a well-developed and efficient drainage system that fingers into most parts of the watershed. Drainages of the north and south forks of Missouri Gulch differ from the rest of the watershed. The eastern part of these drainages, due to a local fault or other geological event, is a sheer rocky ridge.[2/] The channels of these tributaries are nearly at right angles to the main channel. Nearly half of the 6.1 miles of live channel is found in these tributaries.

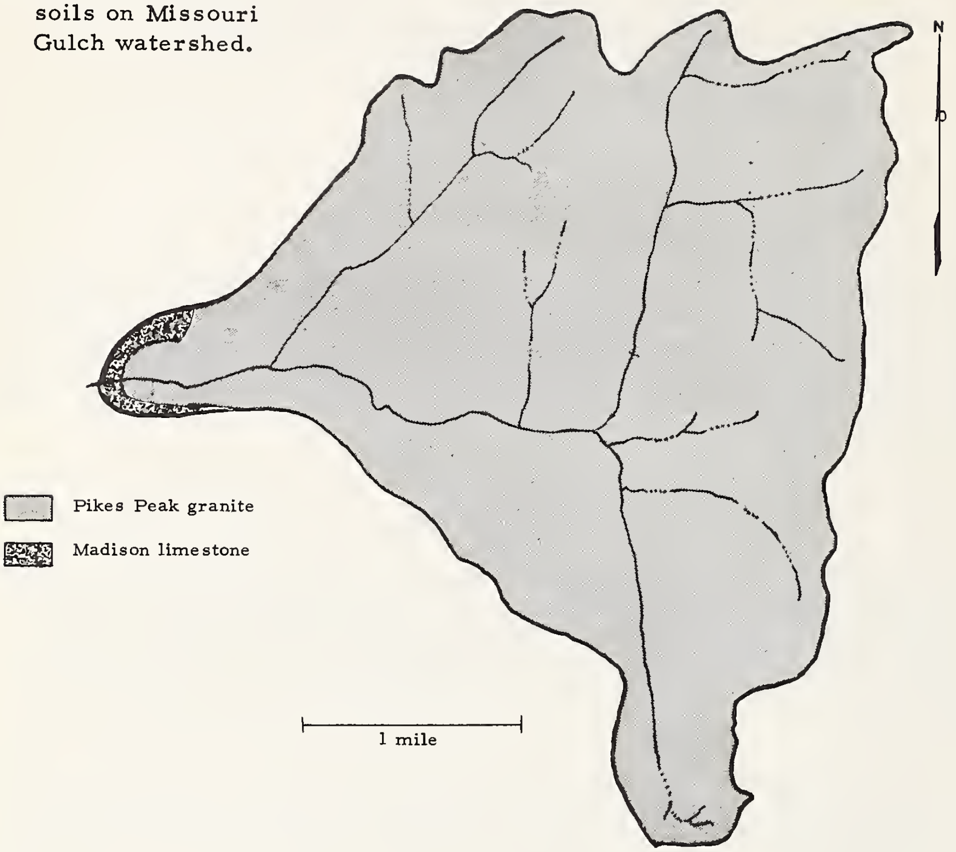
SOILS

Base rock of the entire area is Pikes Peak granite. This formation is overlain by Madison limestone near the mouth of the watershed (fig. 1).

Pikes Peak granite is a coarse-textured rock made up of quartz, orthoclase, and microcline, with biotite as an accessory mineral. Soils developed from this granite are infertile and highly erodible. Madison limestone is a slightly metamorphosed pink or red and gray limestone. Soils developed from this formation are brown to reddish brown and highly fertile.[2/]

[2/] Retzer, John L. Soils and physical conditions of Manitou Experimental Forest. U. S. Forest Serv. Rocky Mountain Forest and Range Expt. Sta., 35 pp., illus. 1949. [Processed.]

Figure 1. -- Geologic origin of soils on Missouri Gulch watershed.



Distribution of residual soils, as well as alluvial fills occurring along drainageways of Missouri Gulch watershed is as follows:

Soil type	Area (Acres)	Proportion of total (Percent)
Edloe gravelly sandy loam[3]	2,123	46.1
Stecum gravelly sandy loam[3]	787	17.1
Chubbs stony loam	114	2.5
Alluvial soils	725	15.8
Meadows and bogs	26	0.6
Bare rock	825	17.9
Total	4,600	100.0

The appendix to this report includes a more complete description of the soil series and types of vegetation.

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[3] Soil names are tentative and are subject to final correlation.

VEGETATION

Parts of Missouri Gulch watershed are covered by stands of overmature timber; however, much of the area has been logged and burned. The watershed is moderately grazed from June 1 to October 30 each year at a stocking rate of approximately 30 acres per cow month. The areas of plant-cover types are as follows:

Cover type	Area (Acres)	Proportion of total (Percent)
Lodgepole pine - Engelmann spruce	1, 119	24. 3
Ponderosa pine - Douglas-fir	1, 372	29.8
Quaking aspen	392	8. 5
Mixture	966	21.0
Brush and grass	352	7.7
Erosion pavement	316	6. 9
Bare rock	83	1.8
Total	4, 600	100. 0

Porosity of the soil mantle is manifested in high infiltration rates. During 1950, infiltration rates in some of the main vegetative types were measured with the Rocky Mountain infiltrometer.[4] From this study it was found that the quaking aspen, mountain brush, and ponderosa pine types had infiltration rates of 4. 30, 3. 22, and 3. 14 inches of water per hour, respectively.

CLIMATE

The climatological station nearest Missouri Gulch watershed is at Manitou Experimental Forest headquarters. This station is located at 7, 740 feet elevation approximately 2-1/2 miles from the stream-gaging station. Here the annual mean temperature is 40. 6° F., and the average annual precipitation is 15. 35 inches (figs. 2 and 3).

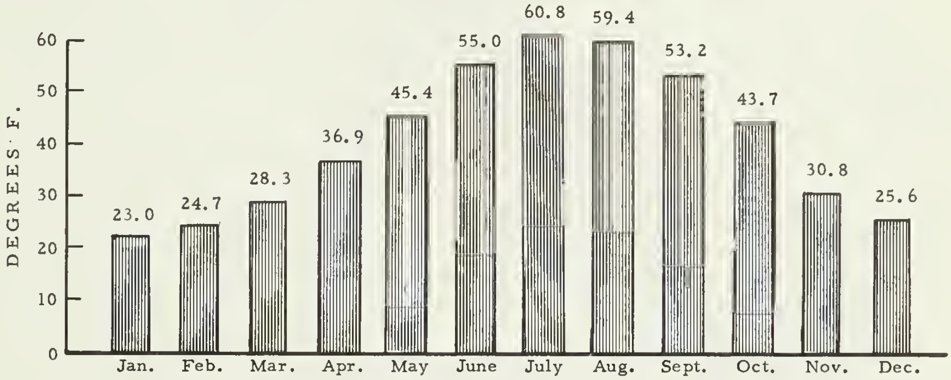

Figure 2. --Monthly mean temperatures, Manitou Experimental Forest headquarters, (1942-58).

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[4] Dortignac, E. J. Design and operation of Rocky Mountain infiltrometer. U. S. Forest Serv. Rocky Mountain Forest and Range Expt. Sta. Sta. Paper 5, 68 pp., illus. 1951. [Processed.]

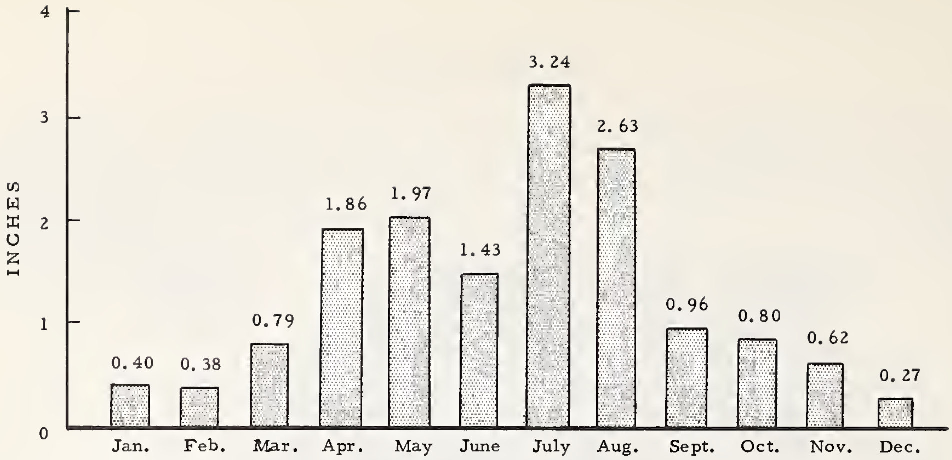

Figure 3.--Monthly mean precipitation, Manitou Experimental Forest headquarters, (1937-58).

Precipitation may be snow from late September through May, but snows commonly melt from south exposures and valleys within a few days. Snow, accumulated during winter only on north exposures, generally disappears by May 20. The potential evapo-transpiration and water balance were computed for the watershed (fig. 4) by using procedures outlined by Thornthwaite and Mather.[5] Temperature data from the headquarters station and precipitation data from Missouri Gulch were used. The moisture regime is characterized by a surplus of moisture through the winter, and a summer period of moisture deficit when evapo-transpiration depletes soil moisture storage.

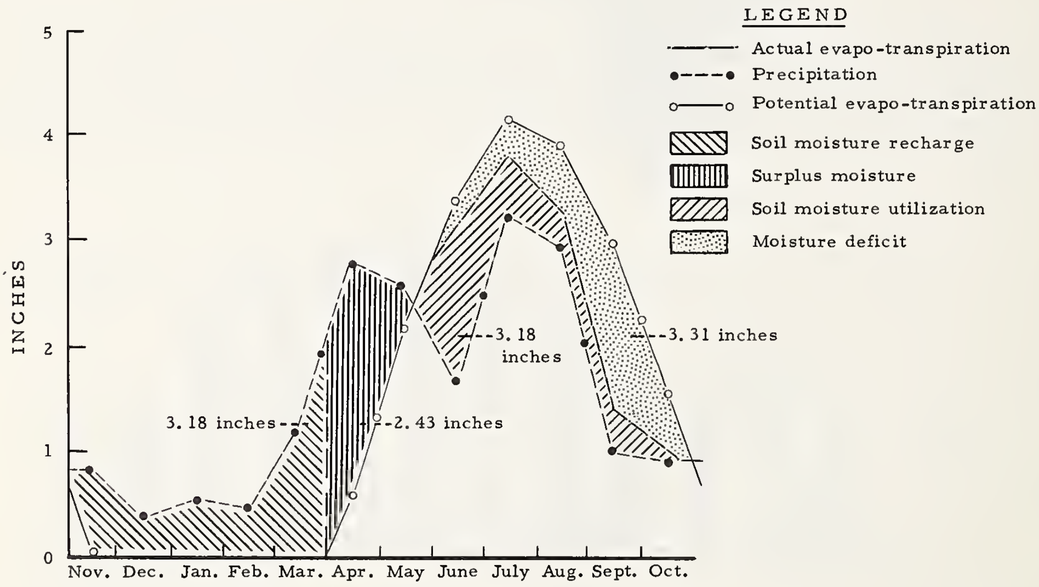

Figure 4.--Water balance for Missouri Gulch watershed.

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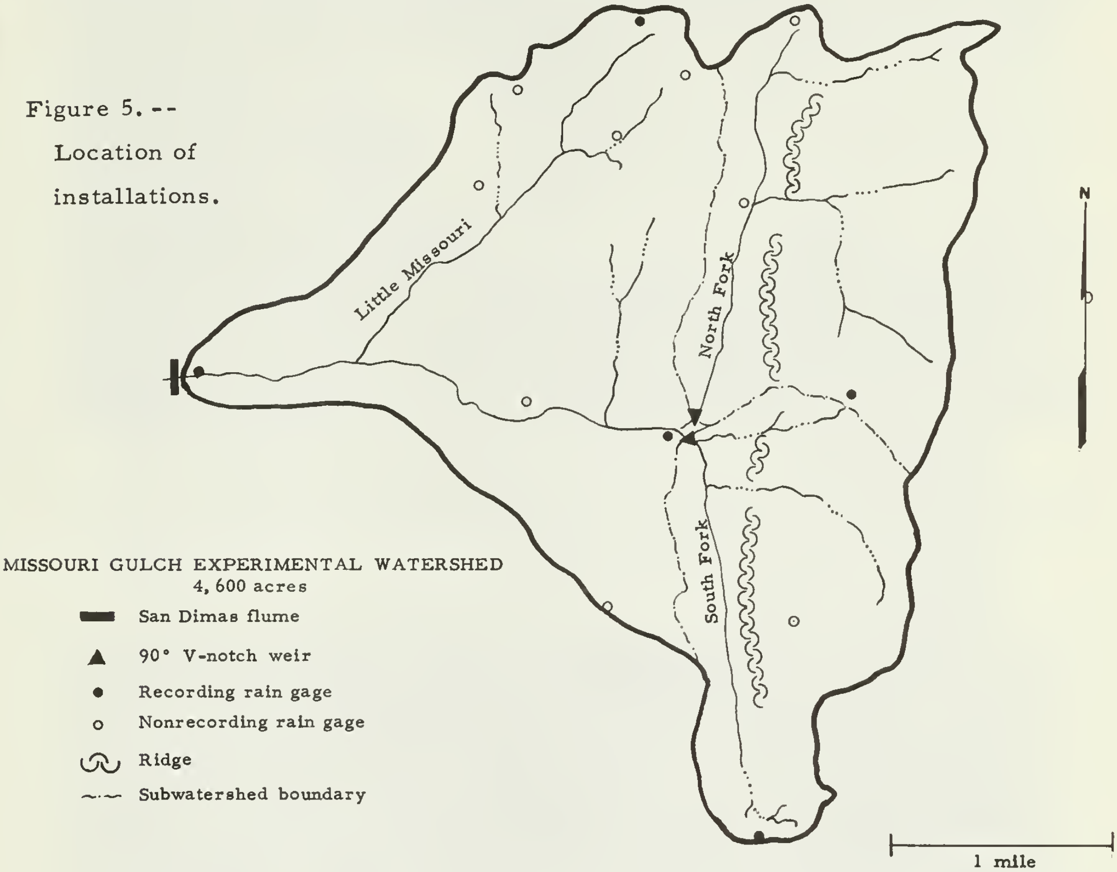
[5] Thornthwaite, C. W., and Mather, J. R. Instruction and tables for computing potential evapotranspiration and the water balance. Drexel Inst. Tech., Lab. of Climatol., Pub. in Climatol. 10(3): 185-311. 1957.

INSTRUMENTATION

Precipitation is sampled by a network of five recording and nine nonrecording rain gages serviced weekly during spring, summer, and fall. Winter precipitation is sampled by 1 recording rain gage serviced weekly and by 13 nonrecording gages measured monthly (fig. 5). None of these rain gages is provided with a windshield; however, snows are seldom accompanied by high winds. During winter these instruments are protected against freezing by a concentrated solution of calcium chloride. Evaporation during all seasons is minimized by a film of oil.

Figure 5. -- Location of installations.



Average depth of precipitation is computed for the watersheds and subwatersheds by the Thiessen method.[6]

Streamflow is measured by a 2-foot San Dimas flume to a head of 1.18 feet. Heads above 1.18 feet are measured by the flume and a 6-foot broadcrested weir (fig. 6). The stream gage rests upon bedrock and is capable of measuring total outflow. However, this gaging station is subject to a severe icing in winter when flows are low. Ice forms in layers in the flume, often building up to a 5-foot thickness during the course of a winter (fig. 7). No practical means of preventing icing without restricting flow has been devised. Consequently, the usable record for this gage is limited to the ice-free period from about April 1 to November 1. The runoff record from the San Dimas flume on Missouri Gulch watershed started in 1940 (see appendix table 2). A description of the flume has been published by Wilm.[7]

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[6] Johnstone, Don, and Cross, William P. Elements of applied hydrology. 276 pp., illus. New York. 1949.

[7] Wilm, H. G. New gaging station for mountain streams. Civ. Engin. 12: 548-549, illus. 1942.

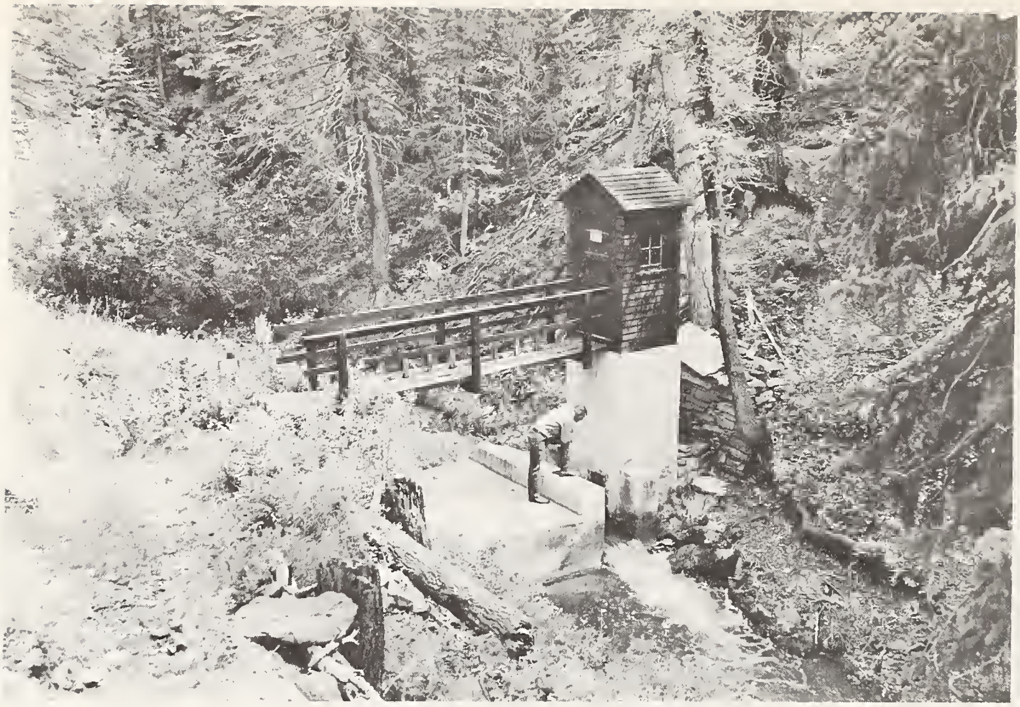

Figure 6.--San Dimas flume installed near mouth of Missouri Gulch watershed.

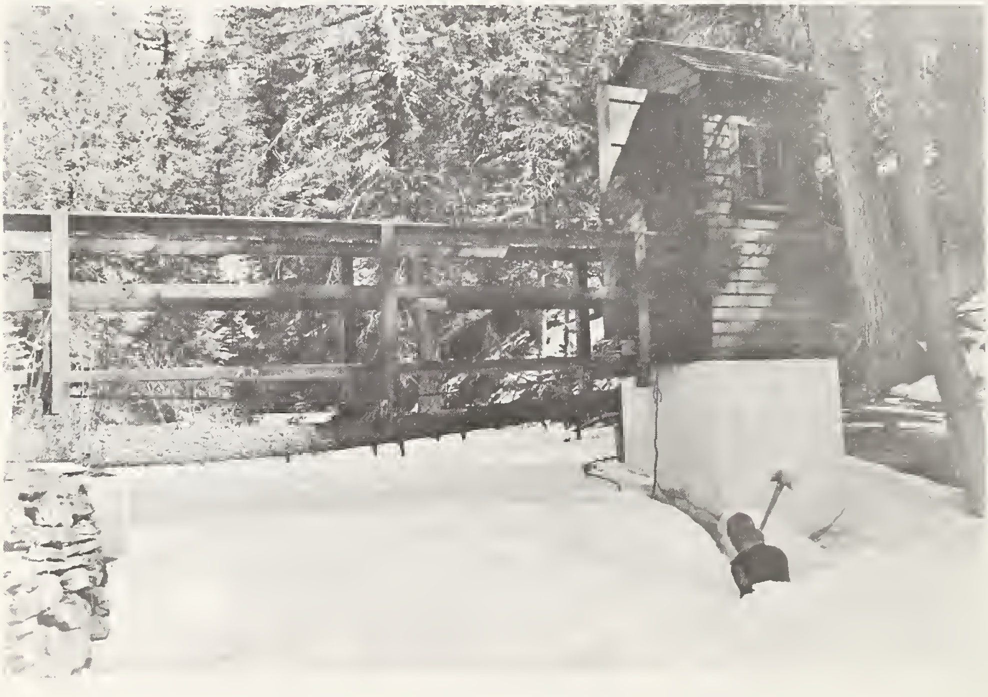

Figure 7.--Clearing winter accumulation of ice from San Dimas flume.

In 1951, 90° V-notch weirs (fig. 8) were installed in the north and south forks of Missouri Gulch to measure tributary flow and to provide an index to winter flow of the entire watershed. Cutoff walls of these gages are a double thickness of 1-inch boards set in a concrete base which extends 2 feet below the original stream bed. As they are not set upon bedrock, these weirs may not measure all flow. However, it is estimated that 90 percent of total flow is measured. Period of automatic record is limited by icing within the stilling wells to approximately the same months as the San Dimas flume--April 1 to November 1. Flow at the notch, however, is rapid enough to keep it free of ice. This allows staff gage readings to be taken during winter periods. Flow is fairly uniform during that season and a good estimate of winter flow is thus obtained (see appendix table 2).

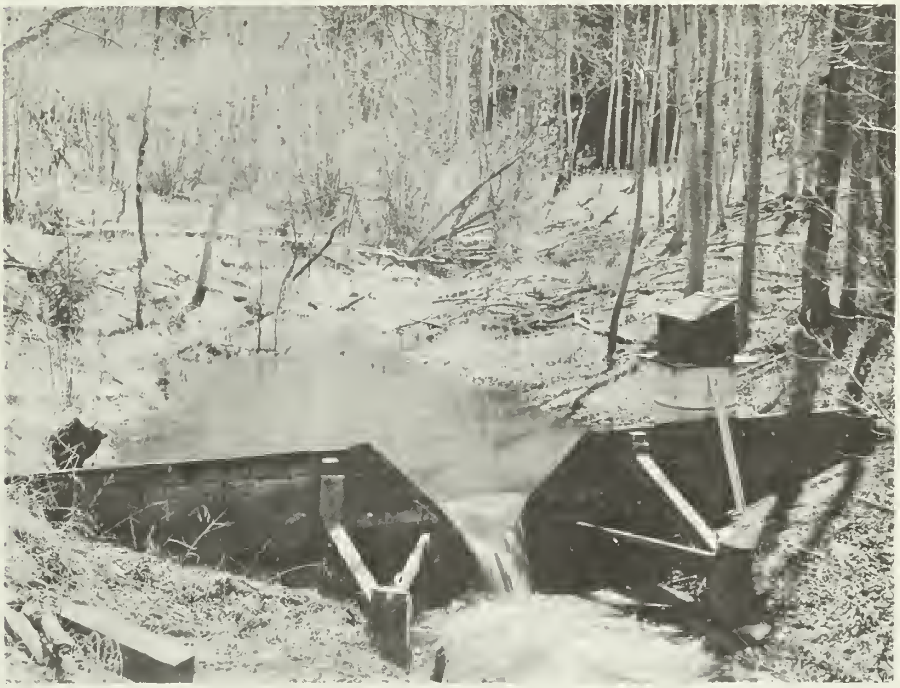

Figure 8. --90° V-notch weir installed in north fork of Missouri Gulch.

A close correlation[8/] was found between the combined flow of the north and south fork drainages and the flow of Missouri Gulch during coincident periods of automatic record. From this relationship, the flow of Missouri Gulch during winter is estimated from the combined flow of the tributaries. (Appendix table 2 summarizes the seasonal flow for the years 1940-58 and estimated total annual flow for water years 1952-58.)

[8/] Regression equation: $Y = 0.034 + 0.701X$. This estimate is based on streamflow measurements for 43 months during the period 1951-58, correlation coefficient, 0.990; standard error of estimate, ± 0.040 area inch.

PRECIPITATION AND STREAMFLOW

CHARACTERISTICS

Total annual precipitation on the watershed ranged from 12.17 inches to 27.05 inches, with a mean of 18.22 inches for the 19 years of the study. Seasonal distribution of precipitation (fig. 9) shows two periods of high precipitation (April-May and July-August). The maximum precipitation intensity, for a 5-minute period, was a rate of 4.80 inches per hour on July 29, 1947.

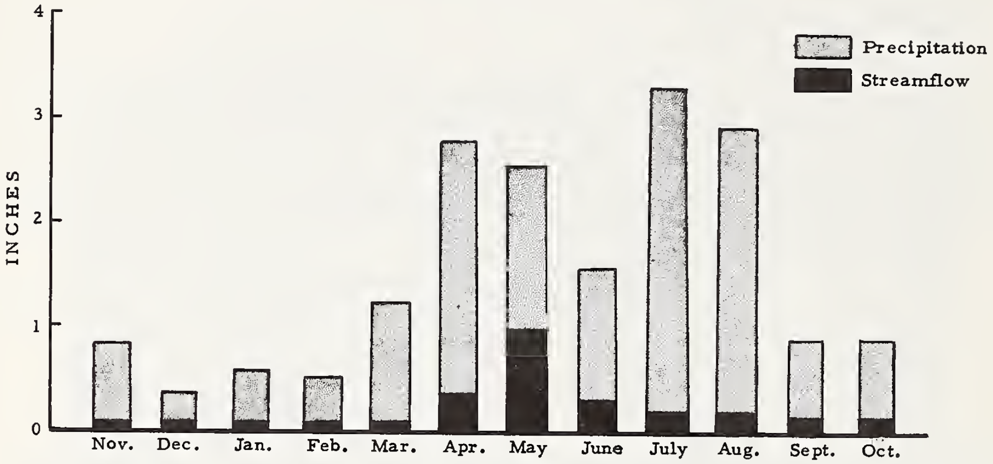

Figure 9. --Monthly mean precipitation and streamflow, Missouri Gulch watershed, 1940-58.

Streamflow from Missouri Gulch is lowest during winter and early spring, rises sharply to a late spring peak, and decreases gradually thereafter. Seasonal streamflow varied from 8.14 inches in 1942 to 0.25 in 1956. Average annual streamflow for the 19 years of study is estimated to be 2.22 inches.

Minimum discharges occurred in October in 10 of the years of record. During 8 other years the minimum discharge occurred in September. The absolute minimum flow for any month recorded was 0.01 inch during October 1956.

Maximum instantaneous discharges resulting from snowmelt occurred as early as April 21 and as late as May 14, but came in April during 10 of the 17 years of record that included spring peaks (table 1). May, however, was the month of maximum total flow during 9 of 11 years of record that included total April and May flow. This is accounted for, in part, by the generally later instantaneous peaks reached on the higher elevation tributaries. Snowmelt from the lower end of the watershed has the greatest influence on the spring peaks, while melt water from higher elevations contributes to the characteristically high May flows.

Table 1.--Spring peak flows, Missouri Gulch watershed, and tributaries, 1941-58

Year	Lower Missouri Gulch		Combined north and south forks, Missouri Gulch	
	Day of peak	Peak flow	Day of peak	Peak flow
		c.f.s.		c.f.s.
1941	April 30	8.14	--	--
1942	April 23	55.82	--	--
1943	May 9	1.87	--	--
1944	May 14	49.68	--	--
1945	May 7	4.21	--	--
1946	April 28	1.78	--	--
1947	May 2	20.92	--	--
1948	April 28	18.40	--	--
1949	April 28	3.86	--	--
1950	April 21	2.13	--	--
1951	April 28	2.03	--	--
1952	May 2	7.82	May 9	1.97
1953	April 29	1.87	--	--
1954	April 30	.49	May 1	.16
1955	(1/)	(1/)	May 10	.33
1956	April 27	.96	April 22	.70
1957	May 9	17.03	May 9	11.28
1958	May 8	10.24	May 9	8.45

1/ Record did not include spring peak.

For correlation with flow from the entire watershed, the flows of the north and south forks of Missouri Gulch were combined. Comparisons of individual annual outflows of these tributaries are as follows:

Water year	North fork	South fork
	(Area-inches)	
1952	1.08	0.53
1953	.63	.57
1954	.09	.07
1955	1.09	.54
1956	.29	.16
1957	5.22	3.86
1958	2.99	2.59
Average	1.63	1.19

Vegetative conditions of these tributaries are quite different, possibly contributing to the difference in streamflow. The south fork drains 1,083 acres and is covered by a stand of mature to overmature timber. The 1,433-acre north fork has only a few trees because of repeated fires prior to establishment of the experimental area.

Sediment production from the entire watershed was not measured, but the 90° V-notch weirs on the north and south forks provided for measurement of coarse sediment deposits in the ponding basins. For the period 1952-58 the average annual sediment production from the north fork drainage was 440 pounds per square mile. This compares closely with 460 pounds per square mile from the south fork basin during the same period.

RELATIONS

Precipitation and estimated total annual outflow of Missouri Gulch watershed for water years 1952-58 are as follows:

Water year	Total precipitation (Inches)	Total flow (Inches)	Precipitation becoming streamflow (Percent)
1952	15.57	1.13	7.26
1953	18.52	.92	4.97
1954	12.86	.48	3.73
1955	17.39	1.03	5.92
1956	13.37	.45	3.37
1957	27.05	3.60	13.31
1958	19.04	2.10	11.03
Average	17.69	1.39	7.86

Of the estimated average annual flow approximately 40 percent occurs in May, mainly from melting snow. Summer precipitation is not effective in the production of streamflow. Through this period nearly all precipitation goes to make up the soil-moisture deficit or is lost to evapo-transpiration.

Annual maximum instantaneous storm peaks on the Missouri Gulch watershed are shown below. In 12 of 18 years the maximum storm peak was recorded in May within 3 weeks after instantaneous spring peak was reached. These May peak flows were the result of rain or very wet snow at a time when the watershed was still charged with snowmelt water. The maximum storm peak of 16.09 cubic feet per second per square mile (c.s.m.) occurred May 10, 1947 when 1.05 inches of rain fell on the snow-covered watershed. The 8.16 inches of precipitation that fell as snow during April 1947 was the most precipitation for a single month during the study.

Day of peak	Peak flow (c.f.s.)	Peak flow (c.s.m.)	Day of peak	Peak flow (c.f.s.)	Peak flow (c.s.m.)
1941--July 26	10.85	1.50	1951--May 21	1.97	0.27
1942--May 8	70.54	9.77	1952--May 20	6.95	.96
1943--May 21	2.14	.30	1953--May 19	6.05	.84
1944--May 27	13.95	1.93	1954--Aug. 13	2.51	.35
1945--Aug. 20	54.20	7.51	1955--May 23	11.86	1.64
1946--July 15	8.55	1.18	1956--July 31	1.91	.26
1947--May 10	116.16	16.09	1957--May 19	21.09	2.92
1948--May 1	10.88	1.51	1958--May 22	11.68	1.62
1949--May 14	14.04	1.95			
1950--June 19	1.17	.16			

The storm hydrograph shown in figure 10 typifies the summer cloudburst storms on the drainage. This storm, which centered on the lower part of the watershed, on July 29, 1947, yielded 0.40 inch of precipitation. Peak runoff came 20 minutes after storm peak. Runoff amounted to 0.0048 inch, or 1.2 percent of the precipitation.

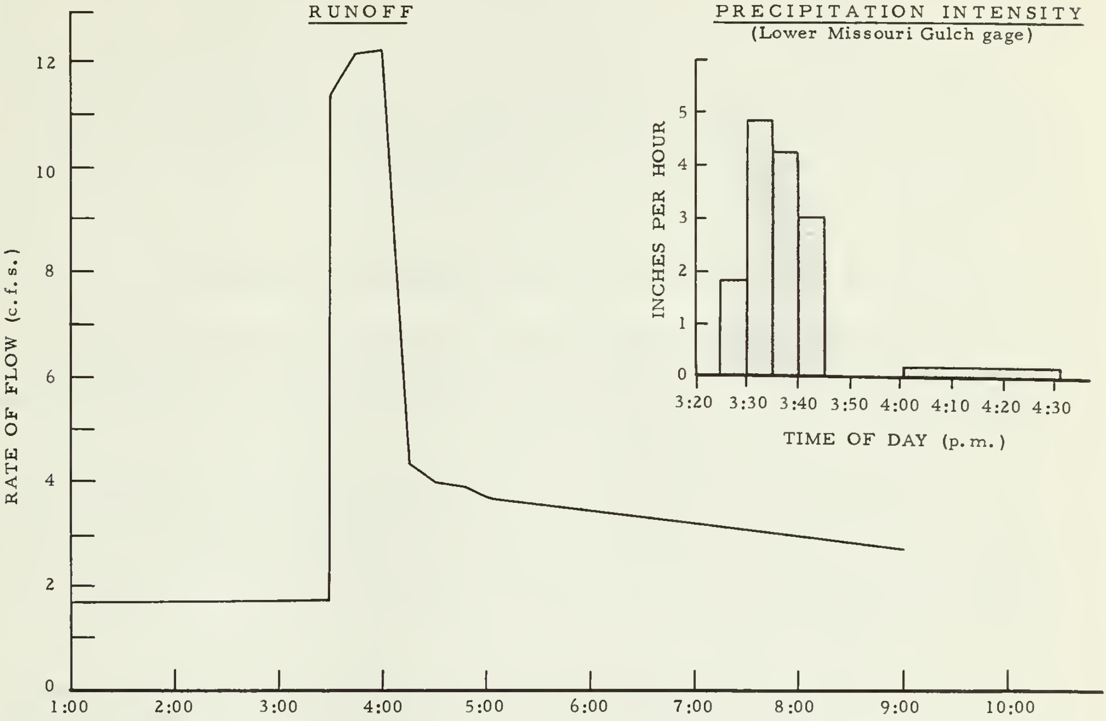

Figure 10.--Storm of July 29, 1947, Missouri Gulch watershed.

DISCUSSION AND SUMMARY

Spring peak flows resulting from snowmelt occur with considerable regularity. Data indicate that these peaks are caused by melting snow on the slopes of the watershed below 8,300 feet. Snowmelt water from elevations above 8,300 feet contributes less to peak discharge and more to the characteristically high May flows, which make up approximately 40 percent of the total yield annually. During summer, streamflow is almost entirely from ground-water reserve.

Winter freezing of the main Missouri Gulch stream gage prevents actual measurement of total water yield. However, inferences drawn in this report are believed to be good estimates of total water yield. Sufficient data were not obtained during the study to predict total annual water yield from total annual precipitation. Water yield is dependent upon precipitation amounts, but the correlation obtained through the present study did not provide an accurate means of predicting streamflow. Such factors as monthly precipitation distribution, storm intensity, and retention storage opportunity exert pronounced but unpredictable effects on streamflow from this type of watershed. During 1952-58, the percentage of precipitation becoming streamflow ranged from 3.73 to 13.31. Average for the period was 7.86 percent.

APPENDIX

SOILS AND VEGETATION

Soils are derived mainly from Pikes Peak granite and Madison limestone, with alluvial fills in the drainageways. Edloe and Stecum [9] gravelly sandy loams, derived from granite, are the most extensive soils of the area.

Edloe gravelly sandy loam, developed on moist north and east exposures and at higher elevations on all exposures, has light brown to grayish surface soils of loose gravelly texture under well developed 1- to 2-inch litter layers. Surface soils rarely extend below 15 inches. Parent material is a loamy gravel with high sand content, resulting from disintegrating bedrock.

Vegetation types associated with the Edloe gravelly sandy loam are lodgepole pine, Engelmann spruce, ponderosa pine, Douglas-fir, and aspen.

Lodgepole pine and Engelmann spruce trees occur either pure or mixed in dense stands at the highest elevations. Where lodgepole pine occurs in pure stands, it is the result of past fires. The sparse understory is made up of low shrubs, some native grasses, and low-growing annuals.

Ponderosa pine and Douglas-fir trees occur in pure or mixed stands. North exposures support moderate to dense stands of Douglas-fir, with scattered ponderosa pine. These exposures are well protected by dense ground litter and understory. A mixture of ponderosa pine, Douglas-fir, and quaking aspen is found along drainageways and on other intermediate sites. These stands have a light to moderate cover of understory vegetation.

Stecum gravelly sandy loam, developed on dry south and southwest exposures, has a pale brown surface soil of loose open gravelly loam, overlain with a thin litter of needles or grass residue. In some areas, the surface is an exposed erosion pavement. Surface soils are rarely deeper than 10 inches. The parent material is a light brown loamy gravel; the gravels are sharply angular and can be dug from the rotting granite bedrock.

Cover types associated with the Stecum gravelly sandy loam are ponderosa pine, Douglas-fir, and on south exposures, brush-grass. Some areas are covered with an erosion pavement.

Ponderosa pine and Douglas-fir grow in relatively open stands, with a sparse understory of mountainmahogany, Arizona fescue, and mountain muhly.

Brush-grass consists of mountainmahogany, mountain muhly, and Arizona fescue, and generally occurs on south exposures. Fair to poor site protection is afforded by the ground cover and litter.

Erosion pavement occurs on south slopes. These slopes support extremely poor stands of ponderosa pine, mountain brush, or native bunchgrass, or are barren. Where vegetation occurs it affords less than 30 percent ground cover. Inadequate cover and litter have resulted in the formation of an erosion pavement on the soil surface. Immediately below the pavement, finer soil particles are found.

9/ Soil names are tentative and are subject to final correlation.

Both the Edloe and Stecum gravelly sandy loams are shallow, coarse, low in organic matter, and relatively infertile. Surface soils are slightly acid but become basic with depth.

Chubbs stony loam, a very fertile soil, derived from Madison limestone, is found only in the lower part of the watershed. The reddish- or grayish-brown surface soils are loose loams or stony loams with well developed soft granular structure, extending 8 to 15 inches deep. The soil is calcareous and contains a high percentage of rock fragments. Subsoil, when present, is a reddish- or grayish-brown heavy loam or clay loam, with granular structure, containing a high percentage of fragmented rock. The parent material is a deep layer consisting of 80 to 90 percent fragmented limestone rock, with loose loam sifted between the fragments.

On Missouri Gulch watershed, ponderosa pine and Douglas-fir are the cover types associated with Chubbs stony loam.

Soils developed from recently deposited alluvium occur in stream beds and on alluvial fans. The surface soils are brown or dark brown, sandy or gravelly loams, 10 to 18 inches thick. They have weak granular structure and are loose when moist but compact when dry. The profiles generally lack a defined subsoil. The parent materials are brown gravels or loamy gravels, often highly stratified. Quaking aspen, in virtually pure stands, generally grows on these soils. The sites are well protected with litter, a dense understory of aspen and conifer reproduction, low shrubs, native bunchgrasses, and numerous annual forbs.

Wet meadows and bog soils have developed from alluvial deposits on small, isolated flood plains through the watershed. Surface soils are dark gray to black gravelly or sandy loams, high in organic matter, and peaty in places. They extend to a depth of 24 inches and are highly stratified. No B-horizon has developed. Parent material is a coarse-textured, stratified gravel or loamy gravel. This layer is mottled or streaked with rust-brown and is characteristically poorly drained.[10/]

Exposed parent rock, generally unweathered granite, occurs on the steepest slopes where there has been little opportunity for soil development. The bulk of this area lies in the east wall of the north and south fork drainages.

[10/] Retzer, John L. Soils and physical conditions of Manitou Experimental Forest. U. S. Forest Serv. Rocky Mountain Forest and Range Expt. Sta., 35 pp., illus. 1949. [Processed.]

Table 7.--Annual precipitation and runoff by water years 1/

(In inches)

Water year	November		December		January		February		March		April		May		June		July		August		September		October		Total precipitation	Total runoff 2/
	Precipi-tation	Runoff	Precipi-tation	Runoff	Precipi-tation	Runoff	Precipi-tation	Runoff	Precipi-tation	Runoff	Precipi-tation	Runoff	Precipi-tation	Runoff	Precipi-tation	Runoff	Precipi-tation	Runoff	Precipi-tation	Runoff	Precipi-tation	Runoff	Precipi-tation	Runoff		
MISSOURI GULCH WATERSHED																										
1940	--	--	--	--	--	--	--	--	--	--	--	0.395	3.97	0.451	0.81	0.353	4.12	0.169	1.76	0.100	2.63	0.055	0.41	0.070	--	--
1941	0.29	--	0.29	--	0.63	--	0.11	--	1.43	--	3.45	.283	2.68	.610	1.59	.243	4.66	.356	4.17	.257	1.89	.235	3.68	.421	24.87	--
1942	.54	--	.72	--	.49	--	.63	--	1.92	--	8.16	2.317	.21	4.322	1.74	.704	1.60	.232	1.74	.135	1.46	.105	2.77	.095	21.98	--
1943	.20	--	.57	--	.27	--	.23	--	.42	--	2.13	--	2.83	.197	1.14	.135	2.25	.060	2.45	.069	.19	.058	.44	.057	13.12	--
1944	.91	--	.39	--	1.23	--	.53	--	3.73	--	4.38	--	2.46	2.542	.57	.615	3.48	.275	1.14	.190	.05	.105	0	.092	18.87	--
1945	.91	--	.18	--	.57	--	.55	--	.49	--	3.38	--	.82	.271	2.23	.084	4.09	.087	7.57	1.522	.61	.298	1.01	.123	22.41	--
1946	.39	--	.19	--	1.08	--	.26	--	.79	--	1.45	--	1.14	.131	1.30	.085	2.86	.051	4.44	.063	.87	.103	1.06	.079	15.83	--
1947	3.76	--	0	--	.35	--	.33	--	.74	--	2.13	--	4.25	2.140	3.41	.703	3.29	.513	3.15	.236	.88	.125	2.66	.211	24.95	--
1948	.83	--	.14	--	.94	--	.84	--	1.08	--	1.44	--	1.38	.756	2.11	.216	3.79	.109	1.28	.089	.74	.057	.07	.069	14.64	--
1949	.60	--	.24	--	.61	--	.59	--	1.65	--	2.50	--	3.34	.692	2.69	.373	5.19	.482	1.68	.116	.65	.056	.63	.057	20.37	--
1950	.21	--	.03	--	.47	--	.64	--	.34	--	1.86	.113	1.73	.098	1.47	.061	3.12	.040	1.65	.029	.54	.025	.11	.041	12.17	--
1951	.62	--	.06	--	.62	--	.47	--	1.41	--	2.32	--	1.39	.141	1.60	.089	1.69	.046	1.86	.032	.38	.023	.91	.018	13.33	--
1952	.50	3/ .039	.71	.040	.09	.040	.66	.040	.76	.049	3.69	.138	2.76	.486	.20	.162	1.73	.044	3.85	.048	.50	.021	.12	.024	15.57	1.131
1953	.86	.038	.44	.037	.16	.036	.45	.038	1.07	.043	2.39	.049	2.43	.342	2.02	.113	4.14	.048	3.66	.080	.37	.041	.53	.052	18.52	.917
1954	.48	.040	.94	.037	.09	.036	.58	.038	.49	.040	.54	.080	1.21	.076	.73	.034	2.91	.018	2.54	.028	2.08	.027	.27	.022	12.86	.476
1955	.82	.035	.42	.035	.38	.036	.46	.037	.72	.040	1.26	.049	5.07	.390	1.39	.229	2.32	.036	3.82	.075	.60	.028	.13	.040	17.39	1.030
1956	.43	.042	.16	.038	.44	.037	.59	.037	1.03	.048	2.03	.013	2.06	.115	.64	.050	3.18	.026	2.05	.025	.15	.013	.61	.010	13.37	.454
1957	1.14	.016	.70	.035	.56	.035	.33	.036	1.82	.059	4.85	.322	4.95	1.459	1.86	.869	5.43	.338	2.67	.242	1.08	.100	1.66	.092	27.05	3.603
1958	1.45	.075	.27	.063	.91	.052	.44	.052	2.44	.073	2.01	.250	3.40	1.017	1.40	.344	1.97	.069	3.07	.040	1.39	.033	.29	.029	19.04	2.097
Average	.83	.041	.36	.041	.55	.039	.48	.040	1.24	.050	2.78	.364	2.53	.855	1.52	.287	3.25	.158	2.87	.178	.90	.079	.91	.084	18.22	2.216
NORTH AND SOUTH FORKS OF MISSOURI GULCH																										
1951	.64	--	.07	--	.66	--	.48	--	1.72	--	2.47	--	1.48	--	1.60	--	1.78	--	1.95	--	.40	.002	.95	.006	14.20	.008
1952	.53	.007	.74	.008	.09	.008	.63	.009	.85	.021	3.71	.051	2.78	.553	.12	.157	1.79	.011	3.89	.008	.50	.003	.13	.007	15.76	.843
1953	.88	.006	.46	.004	.10	.003	.48	.006	1.01	.013	2.39	.029	2.52	.331	2.14	.114	4.01	.029	3.44	.042	.29	.014	.58	.015	18.30	.606
1954	.47	.009	.87	.004	.08	.003	.51	.005	.46	.008	.54	.016	1.23	.030	.76	.003	3.00	0	2.48	0	2.16	0	.27	.001	12.83	.079
1955	.85	.002	.44	.002	.43	.003	.45	.004	.75	.009	1.17	.021	5.00	.508	.93	.256	2.29	.013	3.95	.025	.57	.004	.15	.009	16.98	.856
1956	.44	.012	.16	.006	.47	.004	.72	.004	1.09	.020	2.08	.080	2.10	.088	.67	.015	2.81	0	2.07	.001	.16	0	.62	.003	13.39	.233
1957	1.19	.006	.74	.001	.59	.002	.34	.003	1.92	.036	5.18	.394	5.31	2.131	1.92	1.160	5.58	.448	2.86	.287	1.08	.088	1.65	.083	28.36	4.639
1958	1.55	.058	.26	.042	.98	.025	.47	.026	2.26	.055	2.29	.391	3.51	1.657	1.60	.447	2.03	.069	3.25	.021	1.38	.011	.32	.018	19.90	2.820
Average	.82	.014	.47	.010	.42	.007	.51	.008	1.26	.023	2.48	.140	2.99	.757	1.22	.307	2.91	.081	2.99	.055	.82	.015	.58	.018	17.47	1.435

1/ Water year extends from November 1 to October 31, e.g., water year 1940 is November 1, 1939 through October 31, 1940.
2/ Values shown for Missouri Gulch watershed are estimates.
3/ Values underlined are estimates based on subwatersheds regression.